Two-dimensional investigation of ground temperatures in steep rock slopes

Jeanette Noetzli (1), Stephan Gruber (1), Martin Hoelzle (1) and Thomas Kohl (2)

(1) Glaciology and Geomorphodynamics Group, Department of Geography, University of Zurich, Switzerland
(2) Geomath, AG, Zürich, Switzerland
Contact: jnoetzli@geo.unizh.ch

Photos 1-3: Christine Rothenbühler, Academia Engiadina, Samedan

Introduction
A temperature-dependent reduction in rock-wall stability of alpine permafrost areas, that is likely induced by climate change, has been demonstrated both in theory and laboratory. The delineation of typical locations that are prone to critical temperature changes requires knowledge of the temperature distribution at and below the surface of rock walls.

The effect of high-mountain topography leads to a strong lateral component of heat fluxes. Therefore, ground temperatures and permafrost degradation beneath variable topography such as ridges or spurs can only be investigated where 2- and 3-dimensional effects are accounted for.

Model simulations of typical idealised test cases are performed in order to better understand the complex situations in nature. In this first step, cross sections of various 3-dimensional geometries are explored to describe the distribution of ground temperatures under influence of complex topography. The thermal regime of the subsurface is modified in 3-dimensional cross sections of ridges, peaks or spurs with varying topographical factors such as slope, aspect or elevation.

Topographical factors:
- elevation: high 3500-4500 m a.s.l.
- middle 3000-4000 m a.s.l.
- low 2500-3500 m a.s.l.
- aspect: N, S, E, W

Geometries:
- Ridge
- Ridge with sloped top
- Pyramid
- Spur

Model experiments with idealised geometries
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First Results – ridges

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First Results – other geometries

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Conclusions
- Complex high-mountain topography significantly influences the temperature distribution at depth.
- Isotherms in steep ridges are curved and nearly vertical. A strong heat flux exists from south to north faces and a smaller heat flux from east to west faces.
- The steeper the slope or the closer to the top of the ridge, the more vertical the isotherms, the larger the temperature gradient and the stronger the heat flux.
- 3D effects have to be considered in the context of the delineation of critical temperature zones for rockfall hazards.

Outlook...
- Conduct more experiments with varying input factors and explore the temperature distribution at depth in more detail.
- Forcing of the energy balance model with temperature scenarios in order to investigate time and depth scales of the influence of changing air temperatures on the thermal conditions of the subsurface.
- The results may contribute to identify areas that are especially sensitive for permafrost degradation on maps and serve as a basis for hazard assessment of permafrost related slope instabilities.